

The background of the cover is a dark reddish-brown color. It features several large, faint, stylized chemical symbols and laboratory glassware. In the upper left, there is a large number '4' with a plus sign. To its right is a large 'X' symbol. Further right is a large, stylized tree-like structure with three circular nodes at the top. Below the 'X' is a small flask-like symbol. To the right of the tree is a large, stylized 'T' symbol. In the lower right, there is a large triangle with a plus sign inside, and a circle with a horizontal line through it. On the left side, there is a large, stylized 'A' symbol. The title 'Chemistry for Engineers' is written in a light yellow, sans-serif font across the middle of the cover.

Chemistry for Engineers

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Chemistry for Engineers

This book is dedicated to my wife, Shiao-Ping Siao Yen, Ph.D., formerly (1959-1969) at the Mellon Institute (Fellow, Basic Polymer Science Research), currently (1969-present) at the Jet Propulsion Laboratory, California Institute of Technology (Senior Technical Staff), for her support, understanding, and sacrifice.

FOREWORD

The phrase “Think cosmologically, act globally” conveys what I feel regarding the need for engineers to study science. We all live in this vast universe which is ever expanding its limits and challenging human dimensions. But our actions are limited to his global sphere we inhabit, occupy and can reach out for. Thus codes and regulations are an important instrument for guiding the actions of engineers. But what lies beyond and underneath these regulations is science. Thus to truly understand the workings of these processes, our thinking should be oriented towards the laws of the cosmos, the study of science. Science is involved with knowing the nature and origins of matter. At the microscopic level it is called **physics** and at larger and more complex systems, it translates to **biology**. **Chemistry** is the connecting link in between, which defines the integrating reactions and interactions in this chain.

Presently, I cannot locate any book that addresses the needs of engineers when they want to understand the chemistry, or the science which yields the processes they deal with. This was my motivation to write such a book and making available such a resource. I believe that engineers should be trained in basic science because engineering is an applied science, and it should return to science at higher levels of advanced engineering studies. This book aims at bridging the concepts and theory of chemistry with examples from fields of practical application, thus reinforcing the connection between science and engineering.

As a trained chemist and spending years of experience with research institutes, industries and universities in engineering, I identified the various fields of chemistry that will interest engineers. My doctoral training is in synthetic organic chemistry; other graduate experience is in chemical engineering, biochemistry and mathematics. My post doctorate training is in polymer chemistry and geochemistry. During the last four decades of teaching, my research effort has been in environmental engineering intermixed with petroleum and fuel chemistry.

What chemistry to teach engineers? This answer requires some difficult thought. A straight legitimate way to consider the current curriculum for an engineering program (such as BS in general) requires both general chemistry and calculus based general physics, with at least a two semester sequence of study in either area. As per ABET ruling, a number of engineering disciplines do not require even general chemistry. This is sad especially for the senior level of engineers or post graduate engineers. It is indeed disastrous that a well known military leader cannot construct an emergency runway without the supply of cement.

Perhaps the more adequate definition of engineering is from an ancient Chinese scholar, Jia Yi. He claimed nature such as Heaven and Earth is only a testing tool (reactor) for engineers, and that the pursuit of evolution and understanding of life processes is engineering. This reflects that engineering is logically the reasoning to critically resolve the fundamental problems of great importance.

In this book, specialized topics of chemistry are revisited. The first five chapters, Physical Chemistry, Inorganic Chemistry, Organic Chemistry, Analytical Chemistry, and Surface Chemistry are a review of general chemistry covered in first year undergraduate engineering courses.

For materials, metallurgical and mechanical engineering students, material chemistry, polymer chemistry, and inorganic chemistry become important. For bioengineering and agricultural engineering, biochemistry becomes important, and similarly, for geological engineering, geochemistry becomes important. For manufacturing and petroleum engineering, fuel chemistry is essential. For civil engineering, cement chemistry and asphalt chemistry are important. For environmental engineering and chemical engineering, all twelve chapters are required. According to the real needs of the students, the instructors can arbitrarily delete certain topics.

Since this book is intended to be used worldwide without borders, free selection of the material depends on regional need.

Teh Fu Yen

PREFACE

Having decided to go on this project of making a chemistry book for engineers, the main problem faced was deciding what to write. There was no similar treatise which I could select or look at. The first requirement what I thought for a long while is a good review of the necessary chemistry which links high school chemistry and college chemistry and also a short introduction of the chemistry undergraduate major requirement. These are a total of five different subjects – physical chemistry, inorganic chemistry, organic chemistry, analytical chemistry and surface chemistry. Could the basic concepts of these five subjects become sufficient for review of the essential part of chemistry for the need or basic tools for an accomplished engineer?

The next effort is in determining to what extent any subject should be covered. For example, for organic chemistry, there are thousands of important compounds or nomenclature, thousands of chemical synthesis, thousands of named reactions and thousands of important mechanisms. The question is whether any engineer needs to learn these or familiarize with them. So one has to select, shorten and abstract the necessary basic principles for engineers, with limited space to cover the entire subject. One can always be blamed for being arbitrary and subjective. The author's forty years of experience in teaching engineering students and contacts with engineering societies has solved some of the difficulties which were encountered by others.

I would like to thank the policy of the School of Engineering at the University of Southern California to have this chance of imparting global education without borders. I would also like to acknowledge many colleagues and students without whom this book would not be possible. In particular, I express my gratitude to Ngo Yeung Chan, Zixuan Chen, Neelakshi Hudda, Wanda Tan, and Nishant Vijayakumar.

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CONTENTS

FOREWORD	vii
PREFACE	ix
Chapter 1 PHYSICAL CHEMISTRY	1
1.1 Gas-Liquid-Solid	2
1.2 Thermodynamics	6
1.2.1 Temperature, Heat, and Work	6
1.2.2 The First Law of Thermodynamics	7
1.2.3 The Second Law of Thermodynamics and Entropy Pollution	9
1.2.4 Free Energy	12
1.2.5 Thermodynamic Properties	15
1.2.6 Applications to Solid Systems	21
1.3 Kinetics	24
1.3.1 First-Order Reactions	24
1.3.2 Second-Order Reactions	25
1.3.3 Consecutive Reactions	26
1.3.4 Temperature Dependence of Reaction Rates	28
1.4 Units and Conventions	28
References	34
Problem Set	35
Chapter 2 INORGANIC CHEMISTRY	39
2.1 Structure of Hydrogen Atom and Periodicity	40
2.1.1 Atomic Term Symbols	51
2.2 Bonding and Molecular Shape	54

2.2.1 Rings and Clusters: Huckel Approach and Wade's Rules	55
2.2.2 Ligand Field Theory	61
2.3 The Solid State	64
2.3.1 Metals	68
2.3.2 Alloy System	76
References	79
Problem Set	80
Chapter 3 ORGANIC CHEMISTRY	81
3.1 Structure and Properties	82
3.2 Functional Groups in Organic Compounds	93
3.2.1 Oxygen Functional Groups	95
3.2.2 Nitrogen Functional Groups	97
3.2.3 Sulfur Functional Groups	99
3.2.4 Others — The Halides and Organometallics	99
3.3 Structure Activity Relationship	101
3.3.1 Polycyclic Aromatic Hydrocarbons	103
3.4 Methods for Studying Structure Activity Relationship	106
3.4.1 Molecular Connectivity	106
3.4.2 Factor Analysis	108
3.4.3 Pattern Recognition	109
References	111
Problem Set	113
Chapter 4 ANALYTICAL CHEMISTRY	115
4.1 Acid-Base Chemistry	116
4.1.1 Titration Curve	120
4.1.2 Buffers and Buffer Index	124
4.2 Instrumental Analysis	126
4.2.1 Gamma-ray Spectrometry	128
4.2.2 X-ray Diffraction	128
4.2.3 Mass Spectrometry	129
4.2.4 Ultraviolet/Visible Spectrophotometry	129
4.2.5 Infrared Spectrophotometry	132

4.2.6 Nuclear Magnetic Resonance	133
4.3 Separation Sciences	136
4.4 Chemical Measurements	141
4.4.1 Precision, Errors, and Data Reduction	141
4.4.2 Quality Assurance and Quality Control	145
References	146
Problem Set	147
Chapter 5 SURFACE CHEMISTRY	149
5.1 Colloidal System	149
5.2 Colloidal Range and Adsorption	151
5.3 Surfactants	161
5.3.1 Emulsions	163
5.3.2 Membrane-Mimetic Chemistry	166
5.4 Surface Analytical Techniques	171
5.4.1 Scanning Electron Microscopy (SEM)	171
5.4.2 Scanning Force Microscopy (SFM)	174
5.4.3 X-ray Photoelectron Spectroscopy (XPS)	177
5.4.4 Vertical Scanning Interferometry (VSI)	179
References	185
Problem Set	186
Chapter 6 BIOCHEMISTRY	187
6.1 Cell Chemistry	187
6.2 Amino Acids and Polypeptides	190
6.2.1 Stereochemistry	195
6.2.2 α -Helix	198
6.2.3 β -Sheets	198
6.2.4 Tertiary Structure: Collagen	200
6.2.5 Quaternary Structure	204
6.3 Enzyme Kinetics	206
6.3.1 Michaelis-Menten Equation	209
6.4 Membrane and Clathrin	214
6.4.1 Tubulin, Microtubule and Centriole	214

6.4.2 Superhelicity	221
6.4.3 Spherical Virus	224
6.5 Nucleic Acids and Genetic Information	226
References	237
Problem Set	238
Chapter 7 GEOCHEMISTRY	239
7.1 Plate Tectonics and Natural Resources	240
7.1.1 Hydrothermal Reaction to Mineral Deposits	244
7.1.2 World Phosphate Deposits	249
7.1.3 Tethyan Seaway	252
7.1.4 Rift Basin of South Atlantic Margin	252
7.1.5 Estonian Kukersite Oil Shale	255
7.1.6 Kimmeridge Clay Formation	256
7.1.7 Cordilleran and Andean Belts	258
7.1.8 Western Seaway	258
7.1.9 Rift Depressions in Cretaceous Period	258
7.1.10 Green River Formation	258
7.1.11 Collision of Floating Islands of Panthalassa Ocean in Eastern Asia	263
7.2 Stable Isotopes	265
7.2.1 Geochronology — Radiometric Dating	269
7.2.2 Rb–Sr System	271
7.2.3 Re–Os System	276
7.2.4 ^{14}C Dating	276
7.3 Geochemical Biomarkers	279
7.3.1 Monoterpanes	279
7.3.2 Sesquiterpanes	282
7.3.3 Diterpanes	283
7.3.4 Sesterterpanes	284
7.3.5 Triterpanes	287
7.3.6 Tetraterpanes	289
7.3.7 Polyterpanes	290
7.3.8 Porphyrins	291

7.3.9 Others	291
References	296
Problem Set	298
Chapter 8 FUEL CHEMISTRY	301
8.1 Catalyst Chemistry	302
8.1.1 Surface Area and the Brunauer, Emmett, and Teller (BET) Equation	304
8.1.2 A Universal Carrier — Aluminas	309
8.1.3 Molecular Sieves and Zeolites — Shape Selectivity	310
8.2 Petrochemical Process Chemistry	313
8.2.1 Reactor Design	314
8.2.2 Cracking	321
8.3 Synthesis Gas and Chemical Stocks	323
8.3.1 Fisher–Tropsch Synthesis	323
8.3.2 Organometallics	327
8.3.3 Selective Oxidation and Desulfurization	329
References	331
Problem Set	332
Chapter 9 POLYMER CHEMISTRY	335
9.1 Macromolecular Chemistry	336
9.1.1 Molecular Weight Distribution	339
9.2 Polymerization	342
9.2.1 Stepgrowth Polymerization	343
9.2.2 Chaingrowth Polymerization	343
9.3 Solid State Properties	349
9.3.1 Chain Entanglement and Repetition	350
9.3.2 The Glass Transition	354
9.3.3 Crystallinity	361
9.4 Rubber Elasticity	362
9.4.1 Viscous Flow	370
9.4.2 Linear Viscoelasticity	372
9.4.3 Dynamic Mechanical Testing	378

9.4.4 The William-Landel-Ferry (WLF) Equation and Time-Temperature Superposition	380
References	384
Problem Set	385
Chapter 10 CEMENT CHEMISTRY	387
10.1 Portland Cement and Its Constituent Phases	387
10.1.1 High Temperature Phase Diagram for the Clinkers	392
10.1.2 Hydration of Cement	400
10.2 Pozzolanics Mortars	406
10.2.1 Silicon and Aluminum NMR Studies	408
10.3 Admixture for Concrete Improvement	416
10.4 Concrete Problems and Related Issues	423
10.4.1 Corrosions	423
10.4.2 Behavior of Water in Cement	423
10.4.3 Steel Reinforcement	424
10.4.4 Solidification and Stabilization of Hazardous Waste	426
References	431
Problem Set	432
Chapter 11 MATERIALS CHEMISTRY	435
11.1 Graphite and Diamonds	436
11.1.1 Carbon Fibers	445
11.1.2 Composites	453
11.1.3 Reinforcement Mechanism	458
11.2 Fullerene	464
11.3 Nanotechnology	469
11.4 Ceramics — Piezoelectrics and Electrooptics	475
References	483
Problem Set	484
Chapter 12 Asphalt Chemistry	485
12.1 Naturally-Occurring Bituminous Substances	486
12.1.1 Solubility Parameters	491

12.2 Mesomorphic Material	501
12.2.1 Morphological Distances as Structured Parameters with Diffraction and Scattering Studies	501
12.2.2 Anisotropic Solids as Measured by Electron Spin Resonance Probe	513
12.2.3 Randomly and Highly Substituted Aromatic Homologs by Infrared Bending Frequencies	515
12.3 Colloidal Properties and Average Structure	520
12.4 Rheology of Asphalt	528
References	531
Problem Set	533
 EPILOGUE	 535
 APPENDICES	 541
Appendix A	541
Appendix B	542
Appendix C	543
Appendix D	546
Appendix E	547
 INDEX	 551

PHYSICAL CHEMISTRY

*P*hysical chemistry is concerned with the study of the physical properties and structure of matter using the laws of chemical interaction. Generally, the purpose of physical chemistry is threefold:

- to collect the appropriate data required to define the properties of matter
- to establish the energy relations in physical and chemical transformations
- to predict the extent and rate of the transformation taking place and identify its controlling factors

For our concern as engineers, the principles of physical chemistry could lead to an understanding of such concepts as the identification of compositions in aqueous solutions, the effects of additives on water purification, the extent and prevention of corrosion in piping, and so on. There are two common approaches to understanding physical chemistry. The first is the **synthetic approach**, which begins with the study of the structure and behavior of matter from subatomic particles, electrons, and nuclei, to atoms and molecules, and then proceeds to their